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REPORT ON POLLUTION OF INTERSTATE WATERS
OF THE MERRIMACK AND NASHUA RIVERS
NEW HAMPSHIRE-MASSACHUSETTS

PUBLIC HEALTH SERVICE, BOSTON, MASSACHUSETTS

FEBRUARY 1964

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NEW HAMPSHIRE-MASSACHUSETTS



Division of Water Supply and Pollution Control
Public Health Service
U. S. Department of Health, Education, and Welfare
Region I
Boston, Massachusetts

FEBRUARY 1964

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REPORT ON
POLLUTION OF INTERSTATE WATERS OF
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NEW HAMPSHIRE-MASSACHUSETTS

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Region I
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SUMMARY AND CONCLUSIONS

In a letter dated February 12, 1963, Governor Endicott Peabody of Massachusetts requested the Honorable Anthony J. Celebrezze, Secretary of Health, Education, and Welfare, to call a conference to consider the pollution of the Merrimack River, the Nashua River, and tributaries of these rivers, which affects both the interstate reaches of these waters and the intrastate portions within Massachusetts.

The area covered by this report consists of the entire drainage basin of the Merrimack River in Massachusetts; in New Hampshire it primarily includes the Merrimack River from the state line to Franklin along with the Nashua and the lower Souhegan rivers.

In 1913 the Massachusetts State Board of Health recommended that the cities and towns along the Merrimack River provide waste treatment facilities to reduce the pollution of the river. After 50 years the communities continue to discharge raw wastes to the stream.

Only 23 of 48 jurisdictions responsible for the discharge of sewage in the study area have any type of treatment. Of these 48, only one of 23 discharging directly to the Merrimack main stem provides treatment. Over-all, the existing sewage treatment facilities

reduce the bacterial content of the raw sewage about 23 per cent. Bacteria equivalent to those in the raw sewage from 413,000 persons are discharged to the streams at present, 32 per cent in New Hampshire and 68 per cent in Massachusetts. Sewage which is discharged without any treatment whatsoever accounts for 94.2 per cent of the total.

The suspended solids in discharges of the study area are equivalent to those in the raw sewage of 1,435,000 persons, 82 per cent of which originate in Massachusetts. Industrial discharges account for over 58 per cent of the total. Considering the Nashua River Basin alone, industries discharge over 96 per cent of the suspended solids.

Sewage and industrial wastes presently discharged have an estimated biochemical oxygen demand population equivalent of 987,000 of which 299,000 population equivalents originate in New Hampshire. Existing municipal and industrial pollution abatement measures reduce the original BOD loadings to the streams about 12 per cent.

The Merrimack River is used as the municipal water supply for Lowell and Lawrence, Massachusetts. It is also used for industrial process water, cooling water, and for hydroelectric power.

Certain sections of the Merrimack River in New Hampshire possess an excellent fishery. However, there is a public aversion to eating such fish because of the raw sewage emptied into the river. Fishing in the Merrimack River in Massachusetts is sporadic, with the better fishing being near the mouth. There is little or no anadromous

fishing due to pollution and also because fish passage is blocked by dams. If pollution were adequately controlled, anadromous fish, including salmon, could be reintroduced in the Merrimack River.

The Merrimack River has excellent physical resources for boating and water skiing. Boat racing contests are held in the section above Lowell.

The shellfish areas near Newburyport have been closed since 1926 due to bacterial pollution of the Merrimack River. If the pollution were reduced sufficiently, these areas could be reopened.

At practically no point in the Merrimack River does the bacterial quality of the water meet the objectives for body contact recreational activity. At the Tyngsborough Bridge, in a reach used for recreation, the calculated coliform density was 26 times the Massachusetts limit for bathing. These bacterial densities, derived from sewage, indicate that health hazards are involved in the use of the water for recreation. Near the Lowell and Lawrence water intakes, the calculated coliforms were, respectively, four and 60 times the suggested maximum values for water supplies.

Suspended solids from sewage and industrial wastes produce sludge deposits which reduce or eliminate aquatic life on which fish feed, interfere with fish spawning, and, in severe cases, produce offensive odors. In tidewaters the suspended solids are deposited in the calmer waters along the banks of the Merrimack River during low flow and high tide and then are exposed when the tide is out.

In certain areas an odor nuisance results. Behind the dams at Lawrence and Lowell, deep sludge deposits accumulate. Suspended solids are particularly severe along the Nashua River. Paper fibres are deposited along the river bank, cover the stream bottom, and contribute to the oxygen demand. Black sludge, buoyed up by the decomposition gases, floats on the stream surface causing very unsightly conditions.

During the critical period of the summer of 1963, the Merrimack River had an average dissolved oxygen concentration of 4.5 mg/l or less from above Nashua, New Hampshire, to Amesbury, Massachusetts. Below Lowell and Lawrence, Massachusetts, zero values were recorded. Five mg/l of dissolved oxygen is generally accepted as the minimum DO that is adequate to maintain the maximum potential sport fish population. This minimum is one requirement of the New England Interstate Water Pollution Control Commission for Class C waters. The Nashua River at times becomes septic and gives off foul odors. The conditions of the Nashua adversely affect the use of the river in New Hampshire for fishing.

Visual evidences of pollution which diminish the beauty of the Merrimack and Nashua rivers and are offensive aesthetically include: cloudy or colored appearance of the water below sewage and industrial discharges; condoms floating in the stream or deposited on the banks; oil and grease floating in the water and collecting around boats;

algae blooms; floating black sludge; black colored appearance of the river; and trash purposely dumped into the river.

Wastes discharged to the Nashua River Basin in Massachusetts cause pollution of the Nashua River which endangers the health and welfare of persons in New Hampshire and Massachusetts and therefore are subject to abatement under the provisions of the Federal Water Pollution Control Act.

Sewage and industrial wastes discharged to the Merrimack, Nashua, and Souhegan rivers and colored wastes discharged to the East Branch Pemigewasset River in New Hampshire, along with the wastes discharged to the Merrimack River and its tributaries in Massachusetts, cause pollution which endangers the health and welfare of persons in Massachusetts and therefore are subject to abatement under the provisions of the Federal Water Pollution Control Act.

REPORT ON
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INTRODUCTION

In a letter dated February 12, 1963, Governor Endicott Peabody of Massachusetts requested the Honorable Anthony J. Celebrezze, Secretary of Health, Education, and Welfare, to call a conference to consider the pollution of the Merrimack River, the Nashua River, and tributaries of these rivers, which affects both the interstate reaches of these waters and the intrastate portions within Massachusetts.

On September 23, 1963, Mr. Celebrezze announced that such a conference would be held on February 11, 1964, in Boston.

This report is based on previous reports; data and other material furnished by the Massachusetts Department of Public Health, the New Hampshire Water Pollution Commission, and the New England Interstate Water Pollution Control Commission; information furnished by other interested federal agencies; data obtained by and official records of the Public Health Service; information furnished by the National Council for Stream Improvement; and the 1963 Report on Pollution Control for the Merrimack River in Massachusetts by Camp, Dresser, and McKee, under contract with the Massachusetts Department of Public Health.

The cooperation of the numerous agencies and individuals is gratefully acknowledged.

THE AREA

The Merrimack River Basin has its headwaters in the White Mountains in New Hampshire. The river flows in a southerly direction through New Hampshire and just after entering Massachusetts turns abruptly east for a distance of about 45 miles where it empties into the Atlantic Ocean at Newburyport, Massachusetts. One of its main branches is the Nashua River, which originates in Massachusetts, flows into New Hampshire, and is tributary to the Merrimack River at Nashua, New Hampshire. The main stem of the Merrimack is formed at the confluence of the Pemigewasset and Winnepesaukee rivers at Franklin, New Hampshire, and has a total length of 116 miles, the lower 22 miles of which are tidal. Lands drained by the Merrimack River consist of 5,010 square miles, of which 3,800 square miles are in New Hampshire and 1,210 square miles lie in Massachusetts.

The area covered by this report consists of the entire drainage of the Merrimack River in Massachusetts; in New Hampshire it primarily includes the stream from the state line to Franklin along with the Nashua and the lower Souhegan rivers (Figure 1). The New Hampshire sections were selected on the basis of discharges causing pollution effects on waters within Massachusetts.

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MERRIMACK RIVER

NEW HAMPSHIRE — MASSACHUSETTS

FIGURE 1



BACKGROUND

The water quality condition of the Merrimack River has been of public concern for more than 75 years. Examination of the water for the then existing untreated water supplies for Lowell and Lawrence began in 1887.

The governing body of Massachusetts ordered the State Board of Health to report on the sanitary condition of the Merrimack in 1908, and this report, to the effect that pollution was increasing rapidly, was made in 1909. In 1909 the State Board of Health was again ordered to report, and this report, made in 1913, stated that the objectionable conditions found were due to large quantities of wool scouring wastes, other industrial wastes, and raw municipal sewage being dumped into the river. It also stated that the Merrimack was considerably polluted at the point at which it entered Massachusetts. The report recommended waste treatment by the cities and towns. The Department of Public Health was again ordered to investigate Merrimack River pollution in 1923, and the report was delivered in 1924. This report suggested that the problem could be solved by building sewage and industrial treatment plants locally or by constructing a trunk sewer

from Lowell to the ocean without treatment. The trunk sewer to the ocean was recommended as being somewhat cheaper, with total construction cost estimated at \$9,992,400. In 1928 the Department of Public Health was again directed to investigate pollution in the Merrimack, and this report, made in 1929, indicated a marked reduction in wastes due to the business depression, but the river was still excessively polluted.

The Acts of 1935 created the Merrimack River Valley Sewerage District and the Merrimack River Valley Sewerage Board and provided that they remain in existence only until January 1, 1936, unless \$10,000,000 had been provided by the federal government for construction. No money was appropriated. The Acts of 1936 re-established these entities until January 1, 1938, with no appropriation of funds but with power to start construction if federal funds were donated. In 1937 a special commission was created to study problems of the Merrimack Valley, including pollution of the river. This commission report, made in 1938, recommended the trunk sewer to the ocean with primary treatment at a revised construction cost estimate of \$27,050,000.

In 1936 and 1938 the Federal Works Progress Administration published reports on the Nashua and Merrimack rivers. The two reports list each significant sewage and industrial discharge to the streams along with their specific locations. It was stated that the Merrimack River was considerably polluted in its course through New Hampshire

and that the river as it entered Massachusetts was too polluted for domestic water supply even after treatment but was not objectionable for recreation. The analyses indicated heavy pollution below Lowell and gross pollution below Lawrence and Haverhill. The Nashua River was polluted by domestic and industrial wastes from Fitchburg to the state line.

In 1945 a Joint Board consisting of the Merrimack River Valley Sewerage Board and the Department of Public Health was created to give further study and consideration to the Merrimack River pollution. There was still no money appropriated for construction to alleviate pollution; however, sufficient funds were made available to employ a consultant. The firm of Thomas R. Camp, Consulting Engineers, Boston, was retained. They delivered their complete and exhaustive report to be filed with the numerous others in 1947. This report indicated that during dry weather the Merrimack River was so grossly polluted by domestic sewage that the concentration of bacteria of fecal origin from the state line to the ocean was too high to permit the safe use of the river water for bathing and recreational purposes and for the growing of shellfish for marketing. It also stated that the Merrimack entered Massachusetts with a coliform count in excess of the allowable limit and that, if treatment plants were established in Massachusetts, untreated sewage from New Hampshire would be a menace to the use of the Merrimack River for recreational purposes upstream from Lowell. The report added that organic discharges, primarily from industrial

wastes, grossly polluted the river from Lowell to the sea and resulted in a depletion of dissolved oxygen of the water during dry weather to an extent sufficient to destroy fish life and at times to cause odor nuisance. The engineers determined that construction cost of the trunk sewer from Lowell to the ocean had increased from the original State Board of Health estimate in 1924 of \$9,992,400 to \$50,675,200 as of 1947 with an additional \$5,717,600 to be added for primary treatment. They recommended local and regional collection and treatment as being much cheaper (total construction cost \$27,581,100).

During the succeeding 16 years the important task of studying and reporting on the serious pollution of the Merrimack River Basin was carried on by such entities as the New Hampshire Water Pollution Commission, the Massachusetts Department of Public Health, the New England-New York Inter-Agency Committee, the New England Interstate Water Pollution Control Commission, and the Public Health Service. All of these agencies have done their job well, and the serious conditions in the Merrimack River Basin have been thoroughly documented.

In 1963, fifty years after treatment works were initially recommended for the cities and towns on the Merrimack, the firm of Camp, Dresser, and McKee, Consulting Engineers, Boston, again prepared an engineering report for the Massachusetts Department of Public Health with recommendations and cost estimates for waste treatment construction to alleviate the serious pollution. As expected, the cost for remedial measures again increased.

SOURCES OF POLLUTION

Raw and partially treated sewage and industrial wastes discharge to most of the length of the Merrimack River and several of its tributaries. A summary of the waste discharges to the Merrimack River within the study area is given in Table 1. A similar summary for the Nashua River is presented in Table 2.

The content of waste discharges from either treated or untreated sources may be described in terms of bacterial, suspended solids, or oxygen demand population equivalents. For example, a bacterial population equivalent may be defined as the quantity of coliform bacteria contributed to a stream by the daily untreated discharge from one person.

BACTERIA

Billions of bacteria, frequently including disease-causing organisms, are contained in the daily excreta of each person. If these bacteria are not drastically reduced by suitable treatment of the wastes, large numbers will be found in the streams receiving the wastes. Coliform bacteria, whose normal habitat is the lower

TABLE 1

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to Merrimack River and Tributaries within Study Area

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged					
			Bacterial		Suspended Solids		Oxygen Demand	
			Number	% Total	Number	% Total	Number	% Total
NEW HAMPSHIRE								
Franklin	S-C	None	4,500	1.14	4,500	0.50	4,500	0.54
Boscaven	S-C	None	400	0.10	400	0.04	400	0.05
Brezner Tanning Corporation, Boscaven	-	None	-	-	2,500	0.28	1,500	0.18
Concord (Penacook)	-	None	2,000	0.50	50,000	5.53	32,000	3.84
Penacook Fibre Company, Penacook	-	Wastes recirculated	-	-	230	0.03	200	0.02
Concord	S-C	None	24,000	6.06	24,000	2.65	24,000	2.88
Pembroke	S	None	1,800	0.45	1,800	0.20	1,800	0.22
Allenstown	C	None	1,250	0.32	1,250	0.14	1,250	0.15
Hookset	-	None	1,000	0.25	1,000	0.11	1,000	0.12
State Industrial School	-	None	300	0.08	300	0.03	300	0.04
Manchester	C	None	62,000	15.65	62,000	6.86	62,000	7.43
M Schwer Realty Company, Manchester	-	None	-	-	650	0.07	6,500	0.78
Granite State Packing Company, Manchester	-	None	-	-	19,000	2.10	46,000	5.52
MQM Knitting Mills Inc, Manchester	-	None	-	-	400	0.04	4,000	0.48
Manchester Hosiery Mills, Manchester	-	None	-	-	10	-	50	0.01
Seal Tanning Company, Manchester	-	None	-	-	8,000	0.88	5,000	0.60
Stephen Spinning Company, Manchester	-	None	-	-	400	0.04	4,000	0.48
Waubec Mills Inc, Manchester	-	None	-	-	700	0.08	7,200	0.86
Grenier Air Force Base	S	None	1,500	0.38	1,500	0.17	1,500	0.18

*Type of System: S = Separate Sewers; C = Combined Sewers.

TABLE 1 (Continued)

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to Merrimack River and Tributaries within Study Area

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged				
			Bacterial Number	% Total	Suspended Number	% Total	Oxygen Demand Number % Total
Merrimack (Reeds Ferry)	S-C	None	200	0.05	200	0.02	200 0.02
Merrimack	S-C	None	200	0.05	200	0.02	200 0.02
Merrimack Leather Company,	-	None	-	-	12,000	1.33	7,500 0.90
Wilton	C	None	1,000	0.25	1,000	0.11	1,000 0.12
Hillsborough Mills, Wilton	-	None	-	-	7,000	0.77	3,500 0.42
Milford	C	None	3,000	0.76	3,000	0.33	3,000 0.36
Granite State Tanning Company, Nashua	-	Settling	-	-	12,000	1.33	16,500 1.98
Nashua Finishing Company, Nashua**	-	None	-	-	6,500	0.72	30,000 3.60
Acme Cut Sole Company, Nashua***	-	None	-	-	10	-	325 0.04
Sanders Associates, Nashua****	-	None	-	-	850	0.09	1,200 0.14
Johns-Manville Company, Nashua	-	Settling	-	-	350	0.04	220 0.03
Nashua	S-C	Partly untreated, partly primary, partly secondary	28,500	7.19	28,200	3.12	30,300 3.63
Hudson	S-C	None	600	0.15	600	0.07	600 0.07
Derry	S	Secondary	40	0.01	600	0.07	400 0.05
Salem	C	None	1,000	0.25	1,000	0.11	1,000 0.12
TOTAL NEW HAMPSHIRE			133,290	33.6	252,150	27.9	299,145 35.9

*Type of System: S = Separate Sewers; C = Combined Sewers.

**Closed 12/31/63 but may be reactivated by another firm.

***Once a month 3,000-gallon batch of spent chrome tan solution dumped containing 24,000 mg/l chromium. This probably causes toxic conditions in river during low flows.

****Plating baths periodically dumped. Probably contain copper and cyanide and may cause toxicity problem in stream.

TABLE 1 (Continued)

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to Merrimack River and Tributaries within Study Area

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged					
			Bacterial		Suspended Solids		Oxygen Demand	
			Number	% Total	Number	% Total	Number	% Total
MASSACHUSETTS								
Southwell Combining Company, Chelmsford**	-	Grease recovery	-	-	30,800	3.41	22,100	2.65
H E Fletcher Company, Chelmsford	-	None	-	-	2,940	0.33	150	0.02
Gilet Wool Scouring Corp, Chelmsford***	-	None	-	-	13,600	1.50	19,700	2.36
J P Stevens & Co, Dracut	-	None	-	-	-	-	850	0.10
Dracut	S	None	1,000	0.25	1,000	0.11	1,000	0.12
Chemical Mfg Company, Ashland	-	Neutralization, sand filter	-	-	-	-	500	0.06
General Electric Company, Ashland	-	Neutralization, alkaline-chlorination	-	-	150	0.02	-	-
Marlborough	S	Secondary with Cl2	130	0.03	900	0.10	600	0.07
Westborough	S	Secondary	120	0.03	150	0.02	150	0.02
Hudson Combining Co, Hudson	-	Settling and lagoons	-	-	1,000	0.11	950	0.11
Hudson	S	Secondary with Cl2	70	0.02	1,080	0.12	720	0.09
Maynard	S	Secondary	510	0.13	1,020	0.11	680	0.08
Massachusetts Reformatory	-	Secondary	40	0.01	50	0.01	50	0.01
Concord	S	Secondary	180	0.05	225	0.03	225	0.03
Billerica House of Correction	-	Secondary with Cl2	4	-	50	0.01	35	-
Billerica	S	Secondary with Cl2	20	0.01	100	0.01	75	0.01
No Billerica Co, Billerica	-	None	-	-	1,410	0.16	5,530	0.66
Talbot Mills Inc, Billerica	-	None	-	-	450	0.05	4,120	0.49
Lowell Rendering Company, Billerica	-	Grease recovery	-	-	5,300	0.59	11,000	1.32

*Type of System: S = Separate Sewers; C = Combined Sewers.

**Also discharges 2,380 pounds of grease per day.

***Also discharges 3,120 pounds of grease per day.

TABLE 1 (Continued)

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to Merrimack River and Tributaries within Study Area

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged					
			Bacterial Number	% Total	Suspended Number	% Total	Solids Number	Oxygen Demand % Total
Ames Textile, Lowell	-	None	-	-	735	0.08	2,970	0.36
Vertipile Inc, Lowell	-	Centrifuges	-	-	2,730	0.30	1,560	0.19
Jean-Alan Products Company, Lowell	-	None	-	-	970	0.11	820	0.10
Robinson Top & Yarn Dye Works, Lowell	-	None	-	-	560	0.06	1,230	0.15
United Elastic Co, Lowell	-	None	-	-	290	0.03	650	0.08
Vogue Silver Co, Lowell	-	None	-	-	60	0.01	180	0.02
Middlesex Worsted Spinning Co and Suffolk Knitting Co, Lowell	-	None	-	-	75	0.01	1,120	0.13
Commodore Foods Inc, Lowell	-	None	-	-	1,350	0.15	1,180	0.14
Lowell	-	None	90,000	22.71	91,000	10.06	93,000	11.15
U S Veterans Hospital	-	Tertiary with Cl ₂	-	-	20	-	15	-
State Hospital, Tewksbury	-	Secondary with Cl ₂	26	0.01	130	0.01	130	0.02
Raytheon Co, Tewksbury**	-	Settling	-	-	100	0.01	250	0.03
Andover	S	Partly untreated, partly secondary	8,400	2.12	12,600	1.39	8,400	1.01
Mead Corporation, Lawrence	-	Wastes recirculated, save-allis	-	-	30,600	3.38	13,890	1.67
Oxford Paper Company, Lawrence	-	Wastes recirculated, save-allis, chemical treatment	-	-	51,100	5.65	32,100	3.85
Agawam Dye Works Inc, Lawrence	-	None	-	-	-	-	705	0.08
Merrimac Paper Company, Lawrence**	-	Wastes recirculated	-	-	5,100	0.56	4,400	0.53
Lawrence Wool Scouring Company, Lawrence***	-	Grease recovery	-	-	13,500	1.49	9,180	1.10

*Type of System: S = Separate Sewers; C = Combined Sewers.

**Data estimated by the Public Health Service.

***Also discharges 860 pounds of grease per day.

TABLE 1 (Continued)

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to Merrimack River and Tributaries within Study Area

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged					
			Bacterial		Suspended Solids		Oxygen Demand	
			Number	% Total	Number	% Total	Number	% Total
Loom Weave Corporation, Lawrence**	-	None	-	-	440	0.05	1,760	0.21
Western Electric Company, No Andover	C	None	70,000	17.67	149,000	16.48	120,000	14.39
No Andover	-	Neutralization	-	-	400	0.04	135	0.02
Methuen	C	None	9,000	2.27	18,800	2.08	13,600	1.63
Continental Can Company, Haverhill***	S	None	17,000	4.29	18,000	1.99	23,800	2.85
Hoyt & Worthen Tanning Corporation, Haverhill**	-	Wastes recirculated, save-alls	-	-	77,000	8.51	47,000	5.64
Cowan & Shain Inc, Haverhill	-	Grease and oil recovery	-	-	7,000	0.77	4,400	0.53
C F Jameson Company, Haverhill	-	None	-	-	10	-	790	0.09
Haverhill	-	None	-	-	60	0.01	60	0.01
Amesbury Fibre Corporation, Amesbury	C	None	44,000	11.10	71,000	7.85	50,000	5.99
Merrimack Hat Co, Amesbury	-	Wastes recirculated, save-alls	-	-	6,820	0.75	3,530	0.42
Amesbury Metal Products Company, Amesbury	-	None	-	-	235	0.03	1,120	0.13
Amesbury	-	None	-	-	-	-	-	-
Newburyport	S	None	7,200	1.82	14,000	1.55	11,000	1.32
Salisbury	S	Primary	14,000	3.53	17,200	1.90	15,800	1.89
	S		1,250	0.32	1,100	0.12	1,620	0.19
TOTAL MASSACHUSETTS			262,950	66.4	652,210	72.1	534,830	64.1
TOTAL BOTH STATES			396,240	100.0	904,360	100.0	833,975	100.0

*Type of System: S = Separate Sewers; C = Combined Sewers.

** Data estimated by the Public Health Service.

*** Data furnished by the Continental Can Company.

TABLE 2

Estimated Characteristics of Sewage and Industrial Wastes
Discharged to the Nashua River and Tributaries within Massachusetts

Discharge	Type of System*	Type of Treatment	Population Equivalents Discharged					
			Bacterial		Suspended Solids		Oxygen Demand	
			Number	% Total	Number	% Total	Number	% Total
Cushing Academy	-	Secondary with Cl ₂	3	0.02	45	0.01	30	0.02
State Hospital (Gardner)	-	Secondary with Cl ₂	16	0.10	80	0.02	80	0.05
Crocker, Burbank & Company	-	Save-alls, wastes recirculated, starch substitution, settling	-	-	184,600	34.78	39,650	25.97
Fitchburg Paper Company	-	Save-alls, wastes recirculated,	-	-	108,200	20.39	37,060	24.27
Falulah Paper Company	-	retention aids Vacuum filtration of sludge, chemical precipitation, wastes recirculated	-	-	115,400	21.74	27,940	18.30
Fitchburg Mead Corporation	S-C	Secondary Starch substitution, wastes recirculated	3,150	19.35	6,300	1.19	4,200	2.75
Leominster	S-C	Inadequate secondary	11,000	67.58	11,000	2.07	11,000	7.21
Atlantic Union College	-	Partly primary, partly secondary	210	1.29	210	0.04	280	0.18
Clinton	S	Secondary	1,300	7.99	1,560	0.29	1,040	0.68
Girls Industrial School	-	Secondary	15	0.09	18	0.01	18	0.01
Ayer	S	Secondary	375	2.30	750	0.14	500	0.33
Hollingsworth & Vose Co	-	Settling, wastes recirculated	-	-	1,470	0.27	6,650	4.36
Groton Leatherboard Co	-	Settling, wastes recirculated	-	-	5,880	1.11	2,120	1.39
Groton School	-	Secondary	8	0.05	10	-	10	0.01
St Regis Paper Company	-	Save-alls, wastes recirculated	-	-	64,700	12.19	16,200	10.61
Pepperell	S	None	200	1.23	200	0.04	200	0.13
TOTAL			16,277	100.0	530,723	100.0	152,678	100.0

*Type of System: S = Separate Sewers; C = Combined Sewers.

intestines of warm-blooded animals, including man, are normally used as indicators of recent bacterial pollution.

Only 23 of 48 jurisdictions responsible for the discharge of sewage in the study area have any type of treatment. Of these 48, only one of 23 discharging directly to the Merrimack main stem has any treatment.

The total sewered population of the 48 jurisdictions is estimated to be 533,000. The treatment presently provided is estimated to reduce the over-all bacterial content of the sewage about 23 per cent, leaving bacteria equivalent to those in the raw sewage from 413,000 persons to enter the streams.

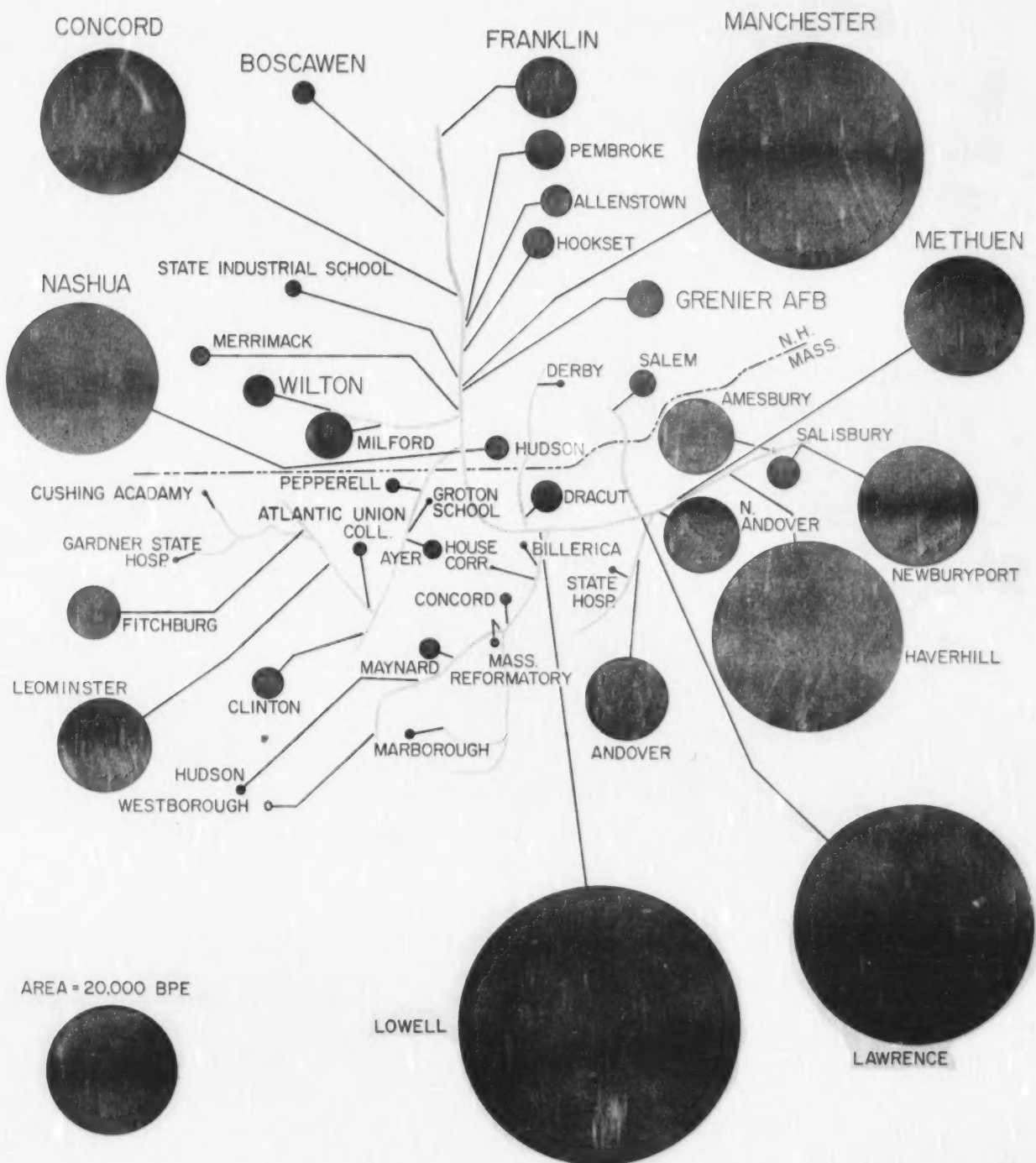
Tables 1 and 2 contain the estimated discharged bacterial loads from the various sewage sources, with estimated allowances for any treatment provided. The data in the tables are presented graphically in Figure 2. This figure provides a visual impression of the relative proportion of the total bacterial load discharged from each source of sewage. The areas of the circles are in proportion to the loads from the various jurisdictions.

Of the estimated total bacterial loads, including the Nashua River, 32 per cent is discharged in New Hampshire and 68 per cent in Massachusetts. Sewage which is discharged without any treatment whatsoever accounts for 94.2 per cent of the total.

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ESTIMATED BACTERIAL LOADS

FIGURE 2



The four largest individual bacterial loadings to the Merrimack River come from Lowell, with 22.7 per cent; Lawrence, with 17.7 per cent; Manchester, with 15.6 per cent; and Haverhill, with 11.1 per cent. All four discharge their sewage raw, and combined they account for two thirds of the total bacterial load.

In the Nashua River Basin, the town of Leominster is responsible for most of the bacterial discharges due to inadequate sewage treatment facilities. Only one town, Pepperell, discharges raw sewage.

SUSPENDED SOLIDS

Suspended solids data were not available for several industrial sources and had to be estimated from known loadings from other plants with similar operations. The over-all suspended solids discharges to streams of the study area are equivalent to that in the raw sewage of approximately 1,435,000 persons. Of this loading, approximately 1,183,000 population equivalents originate in Massachusetts. Over-all, an estimated 836,000 suspended solids population equivalents are discharged directly by industry and 599,000 by municipal or domestic sources. In the Nashua River Basin alone, over 96 per cent of the 530,700 population equivalents of suspended solids are discharged by industries.

By far the largest source of suspended solids come from the three paper industries of Fitchburg, Massachusetts. About 408,000 population equivalents, over one fourth of the suspended solids in the

entire study area, come from Crocker, Burbank & Company, Fitchburg Paper Company, and Falulah Paper Company of this town. Other large sources of suspended solids are the discharges from Lawrence, Massachusetts, with 250,000 population equivalents, and the discharges from Haverhill, Massachusetts, with 155,000 population equivalents.

BIOCHEMICAL OXYGEN DEMAND

Sewage and industrial wastes presently discharged to the streams have an estimated biochemical oxygen demand population equivalent of 987,000. It is estimated that existing municipal and industrial pollution abatement measures reduce the original BOD loadings to the streams by 12 per cent.

Contributions of wastes with large biochemical oxygen demand are the discharges from Lawrence, Massachusetts, with 182,000 population equivalents; discharges from Manchester, New Hampshire, with 135,000 population equivalents; discharges from Fitchburg, Massachusetts, with 109,000 population equivalents; discharges from Lowell, Massachusetts, with 103,000 population equivalents; and discharges from Haverhill, Massachusetts, with 102,000 population equivalents. New Hampshire discharges account for 299,000 population equivalents and Massachusetts discharges for 688,000 population equivalents. Over-all, 463,000 population equivalents of BOD are discharged directly by industries while 524,000 population equivalents are discharged by non-industrial jurisdictions. Eighty-nine per cent of the BOD

discharged to the Nashua River in Massachusetts comes from industry. Figure 3 presents the data in a graphical form.

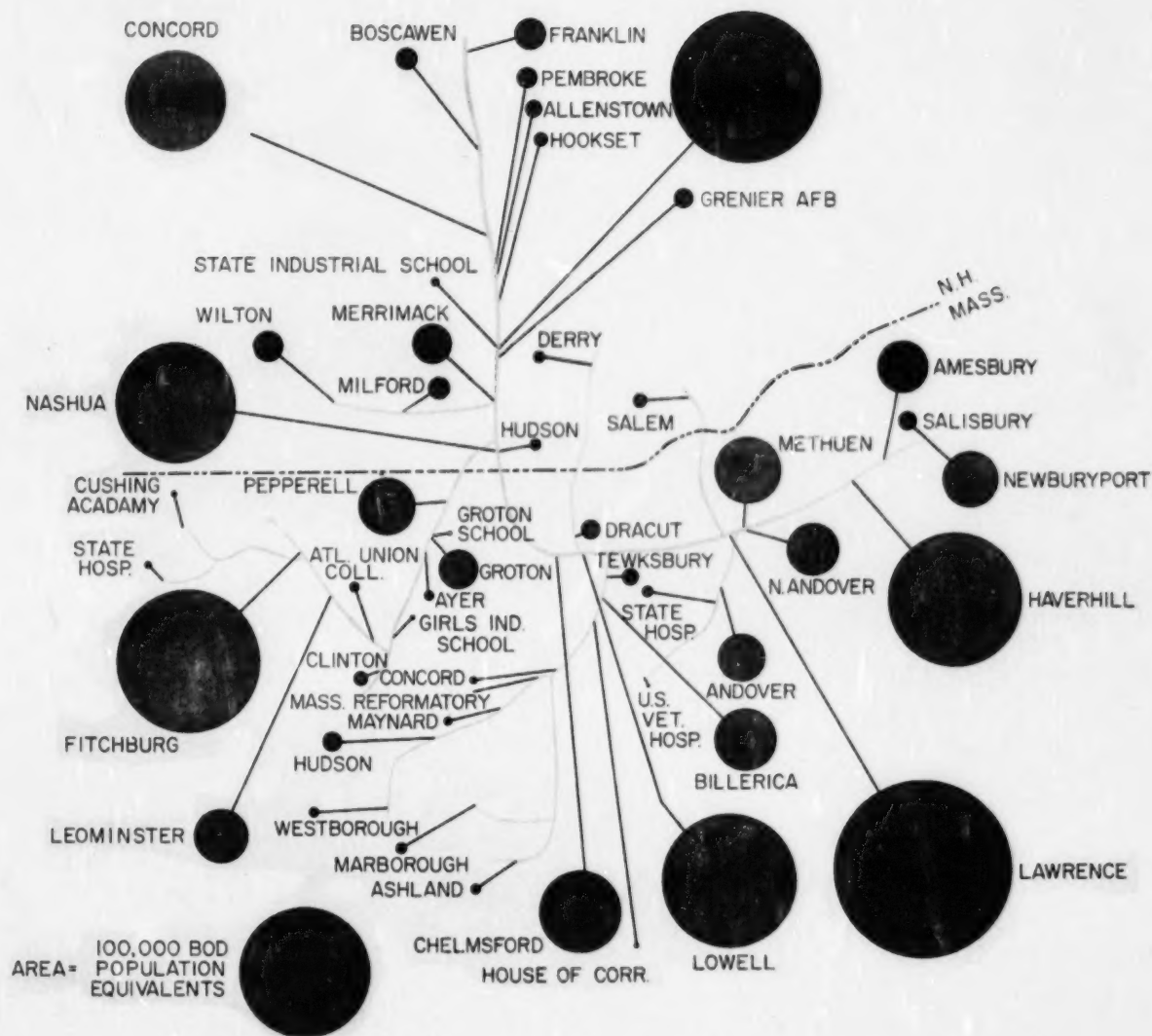
MISCELLANEOUS

Several other waste constituents are important when considering the quality of water. The wool scouring operations in Chelmsford and Lawrence contribute over three tons per day of grease to the Merrimack River. At the Acme Cut Sole Company in Nashua, New Hampshire, the spent chrome tanning solution is dumped into the stream once a month. The solution contains 24,000 mg/l chromium. Plating baths are periodically discharged from Sanders Associates, Nashua, New Hampshire, and from several industries in Massachusetts. These wastes normally contain cyanides and heavy metals and could cause toxic conditions in the receiving streams. Natural color is prevalent in a number of streams in the Merrimack River Basin. However, it is estimated that 15 per cent of the color in the Merrimack River at Lowell, Massachusetts, originates at the Franconia Paper Corporation pulp mill at Lincoln, New Hampshire. The wastes from this company also contain biochemical oxygen demand equivalent to the raw sewage from approximately 400,000 persons. Although this BOD results in a severe local problem, its effects do not extend to Massachusetts as does the color.

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BIOCHEMICAL OXYGEN DEMAND LOADS

FIGURE 3



WATER USES

MUNICIPAL USE

Since January 1963 the Merrimack has been used as the principal source of water supply for the city of Lowell, Massachusetts. Approximately 65,000 persons are served by this treated supply. Lowell's water intake is located seven miles below the New Hampshire-Massachusetts state line. Lawrence, Massachusetts, has been using the Merrimack as a source of municipal water supply since 1893, with an estimated 90,000 persons being served by the treated supply. Treated water from Lawrence is supplied to the neighboring town of Methuen.

Billerica uses the Concord River for its source of municipal water supply. A new water treatment plant was completed in 1955 for this purpose.

With the rapidly increasing populations in many of the cities and towns along the Merrimack River, additional municipalities may need to make use of this convenient source of water supply. Chelmsford, Tyngsborough, Andover, and Tewksbury, Massachusetts, have already been

mentioned as potential users of the Merrimack. Burlington is considering the use of the Shawsheen River during part of the year.

INDUSTRIAL USE

In 1954 approximately 185 million gallons per day of water were taken from the Merrimack River for industrial water use in the major industrial centers of Manchester, New Hampshire, and Lowell, Lawrence, and Haverhill, Massachusetts. Another 27 million gallons per day were taken from the North Nashua River by the Fitchburg industries. Industrial water use has probably been reduced because a number of the major water-using industries have moved out of the basin. About half of the industrial water use in 1954 was for cooling purposes.

Some industries use the Merrimack River for process water, even though the water quality is not good. Sand filters are used to precondition the process water. Feeder streams also are used for industrial water supplies.

Nashua River water is used for industrial process water in a number of instances. Where necessary to precondition the water, facilities ranging from coarse sand filters to ion exchange processes are used.

The Merrimack River is used for hydroelectric power to a large extent. On the Merrimack below Franklin, New Hampshire, there are five utility plants and 13 privately-owned industrial developments with total capacities of 28,670 and 22,320 kilowatts, respectively.

These 18 plants utilize 177 feet of a total fall of 254 feet. Canal systems at Lowell and Lawrence, Massachusetts, divide the use of water among several plants at each location. During periods of low flow the Merrimack River flow below several of the dams is drastically reduced on weekends. This two-day reduction in flow seriously affects the capacity of the river to assimilate wastes.

RECREATION

Water-oriented recreational activity has been increasing rapidly on a national scale, especially near centers of population. However, the very real potential of the Merrimack River for recreational uses has not been fully realized. The U. S. National Park Service in 1954 estimated that, with the implementation of the recreation plan proposed, tangible benefits of 15 million dollars annually would be added to the economy of the Merrimack Basin. Highly significant intangible benefits would also be involved. No doubt the benefits would be greater today because of the increased pressure for recreation.

Fish and Wildlife

According to the U. S. Fish and Wildlife Service, parts of the Merrimack River in New Hampshire possess an outstanding fishery. However, there is a public aversion to using fish caught from the river for food because of the raw sewage emptied into the river. Any

fishing is just for sport. Fabulous potential exists for fishing which may materialize if the pollution is cleaned up.

The Merrimack River between the Nashua River and the state line contains the following fish species in numbers: yellow perch, red-breasted sunfish, pumpkinseed, large-mouthed bass, eastern chain pickerel, northern yellow bullhead, northern common bullhead, eastern golden shiner, eastern common shiner, fallfish, long-nosed dace, eastern black-nosed dace, and eastern common sucker.

The Merrimack River from Amesbury to the mouth is heavily fished for striped bass.

Prior to construction of the dams on the lower Merrimack, hundreds of thousands of anadromous fish were caught annually in the Merrimack River. The most important species included salmon, shad, alewives, and smelt. The Merrimack River was famous for its salmon run, but this completely disappeared about 1920. Its disappearance is attributed, in part, to the dams and to pollution.

According to the U. S. Fish and Wildlife Service, the present shad run into the Merrimack is small, since the only area available for spawning, the lower section of the river, is heavily polluted. Fish can ascend the fishway in the Essex Dam at Lawrence and then proceed upstream to the Pawtucket Dam at Lowell which is impassable. The number of shad annually ascending the Lawrence fishway is from 1,500 to 3,000 fish. Fishing for shad in the lower river is sporadic,

and in some years there is none at all. In 1960 no fish were reported taken.

Officials of the U. S. Fish and Wildlife Service have stated that, if the polluted conditions in the Merrimack River were eliminated, fish elevators could be built at the dams and anadromous fish, including salmon, could be reintroduced in the Merrimack River.

Because of the polluted conditions in the Nashua River, it is not used for fishing. This river is populated by various types of coarse fish in the New Hampshire section. Based on the character of the stream, it appears that improvement of its water quality would make recreational fishing possible.

The tidal marsh and mud flat complex in the Newburyport-Amesbury area is a large important waterfowl area. Another important waterfowl area is in the Nashua River Basin, particularly in the Lancaster-Bolton, Massachusetts, area.

Boating and Water Skiing

The Merrimack River is used for boating and water skiing from Lowell to the New Hampshire state line, above Lawrence, and in the tidewater near its mouth. Ski clubs have been formed by persons with this mutual interest, and ski jumps are provided for members. The Eastern Stock Outboard Boat Racing Championships were held in the Merrimack River above Lowell for the past two years, indicating the popularity of the river for boating. In the Nashua River there is a

small amount of boating in the reservoir above Pepperell, and the Concord River is utilized for this purpose in Billerica.

Bathing

Lowell provides a public bathing beach and a change house along the Merrimack upstream of the city. The only other known bathing on the main stem takes place in the tidewater near the mouth of the river.

SHELLFISH

The soft-shell clam flats in the area of Newburyport, Massachusetts, at the mouth of the Merrimack River are highly polluted, largely as a result of sewage discharged to the river by neighboring communities. For that reason the beds were closed to shellfish taking in 1926 and have remained closed to date.

EFFECTS OF POLLUTION ON WATER QUALITY AND USES

BACTERIAL POLLUTION

Municipal sewage contains enormous numbers of bacteria, among which there are frequently pathogenic bacteria that can cause gastrointestinal diseases such as typhoid fever, dysentery, and diarrhea. The pathogenic organisms, in densities too low to be detected by available laboratory procedures, can cause illness in persons who swallow water containing them. Infectious hepatitis, a virus disease, can also be caused by ingesting sewage-polluted water; and eye, ear, nose, throat, or skin infections may result from bodily contact with such waters. If the densities of pathogenic organisms are reduced by sewage treatment, dilution, or by natural self-purification, the hazards of contracting disease are proportionately reduced.

Sewage also contains bacteria of the coliform group which can readily be detected even at low densities. These bacteria, although harmless in themselves, are indicators of the probable presence of pathogenic bacteria and viruses. Coliform organisms are therefore used as a tool in evaluating bacterial pollution of streams and are used as a basis for water quality objectives for various water uses.

The results of coliform determinations are expressed in terms of most probable numbers (MPN) per 100 milliliters (ml) of water. One hundred milliliters is a little less than one-half cup. The coliform group usually is designated as total coliforms.

For municipal water supplies the New Hampshire limit is a mean of 1,000 coliform bacteria per 100 milliliters, provided the water treatment is adequate. Massachusetts has no definite limit, although a mean of not more than 5,000 MPN/100 ml is used as a guide.

Both states have standards for stream classifications involving bathing and recreational use of the streams. Water skiing is a sport involving bodily contact with water and may be considered a recreational use under the classification with coliform limits similar to those used for bathing. The Massachusetts limit is a mean of 2,400 MPN/100 ml, and in New Hampshire a logarithmic average of 240/100 ml is the limiting value. Neither state has adopted a total coliform objective of water quality for recreational uses in Class C waters, even though the uses of Class C waters include boating and fishing. Where such an objective has been adopted in other states, the commonly used limit is 5,000 MPN/100 ml. Where the water use demands, disinfection of a sewage effluent may be required in both New Hampshire and Massachusetts.

Based on present sewage discharges along the Merrimack River and flows of 1,000 cubic feet per second, the coliform bacteria densities were calculated. These densities are presented in Figure 4

for the river from Franklin, New Hampshire, to the mouth. Values range from 1,900,000 MPN/100 ml below Lawrence, Massachusetts, to 2,700 MPN/100 ml just above Amesbury.

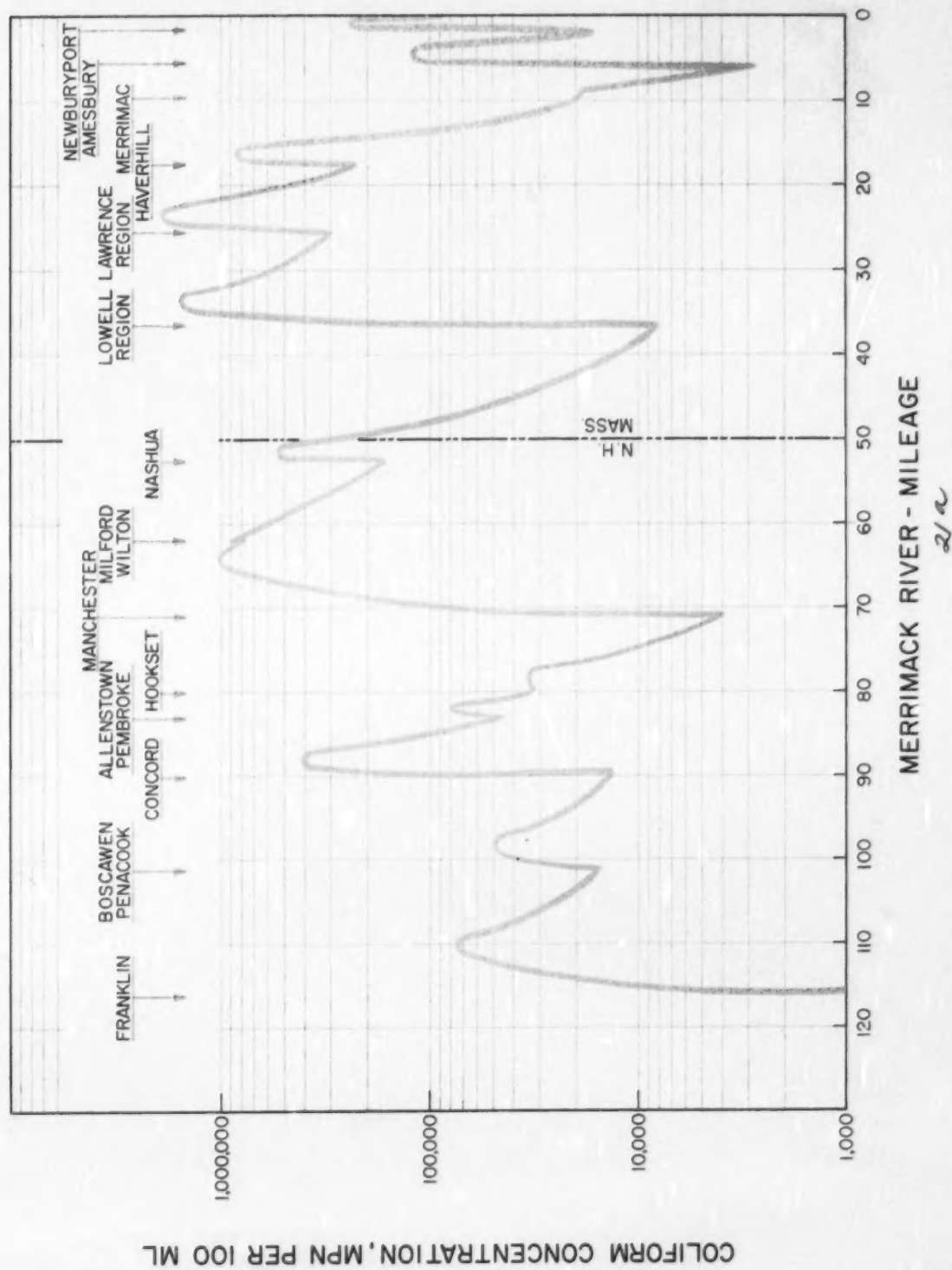
A density of 210,000 per 100 ml was calculated at the New Hampshire-Massachusetts state line, and 21,000 per 100 ml at the Lowell municipal water intake, over four times the maximum used as a guide for water supplies in Massachusetts. At Tyngsborough Bridge, in the section used for recreation, the calculated coliform value was 63,000 per 100 ml, 26 times the Massachusetts limit for bathing. At this point a drop of water sprayed into the face of a boater or water skier may contain 42 coliform bacteria.

During July and August of 1963 the Merrimack River flows were very close to the 1,000 cfs used in the calculations and afforded an opportunity to compare these coliform densities to the results obtained for samples collected by Massachusetts and New Hampshire personnel during this period. The comparison was made at several key points near the state line. Average values for the samples were 28,000 MPN/100 ml above the Nashua River, 28,000 MPN/100 ml 1.6 miles below the state line, 46,000 MPN/100 ml at Tyngsborough Bridge, and 13,000 MPN/100 ml at the Lowell water intake, compared to calculated values of 22,000, 90,000, 63,000, and 21,000, respectively. The agreement is considered reasonably good.

The highest coliform concentration in the New Hampshire section of the Merrimack River occurs below Manchester where

COLIFORM CONCENTRATION VS MERRIMACK RIVER MILEAGE

FIGURE 4



1,000,000 per 100 ml was calculated. Figure 4 shows that, in Massachusetts, extremely high coliform concentrations occur below Lowell, Lawrence, and Haverhill. Even at the mouth of the Merrimack River the calculated coliform density was high. Over-all, the Merrimack River is a health hazard with any bodily contact from Franklin, New Hampshire, to just above its mouth, a distance of 116 miles.

At Lawrence, where the river is used for the municipal water supply, the coliform bacteria were calculated to be 300,000 per 100 ml, 60 times the maximum used as a guide for water supplies. Average values obtained by the Massachusetts Department of Public Health just above Lawrence were 56,000 MPN/100 ml during their 1962 survey and 15,000 MPN/100 ml during their 1963 survey. The high bacterial density necessitates expensive treatment costs and very careful water plant operation to make the water safe to drink.

The calculated coliform value at the mouth of the Merrimack River was 96,000 MPN/100 ml. Results obtained by the Massachusetts Department of Public Health showed an average of 540 MPN/100 ml, with a maximum value of 3,500 MPN/100 ml near this point during their 1963 survey. The procedure for estimating residual coliform organisms from sewage discharges did not take into account the large dilution available from incoming ocean tides and would tend to overestimate the actual coliform densities in this section of the Merrimack River. In either case, however, the coliform density was considerably in excess

of the maximum of 70 per 100 ml permitted for the unrestricted taking of shellfish.

Throughout most of the Nashua and North Nashua rivers, the coliform densities are excessive and indicate a hazard to recreational users. The very high bacterial densities in Massachusetts are reduced by natural purification during the flow to the state line, and at Hollis Depot, New Hampshire, just across the state line, ten samples obtained in 1963 yielded a maximum of 9,300 MPN/100 ml and a mean of 2,600 MPN/100 ml.

The elimination of the shellfish industry near Newburyport, Massachusetts, by bacterial pollution has been mentioned. A preliminary estimate by the Massachusetts Department of Natural Resources indicates that the direct and indirect benefits associated with the reactivation of the shellfish industry in this area would be worth approximately three million dollars annually if pollution were adequately controlled.

SUSPENDED SOLIDS

Excessive suspended solids in a stream diminish the beauty of the water and settle to the stream bottom where they form sludge deposits which can produce offensive odors, reduce or eliminate aquatic life on which fish feed, and interfere with fish spawning.

When suspended solids flow through a slow-moving section of a stream such as an impoundment, the particles tend to settle out.

The blanket of sludge on the bottom of the river covers the areas which otherwise would be used by fish in spawning and thereby reduces the fish population below its potential. In addition, the sludge-covered bottom is not a suitable habitat for the insect larvae and other aquatic life which normally live on the bed of a clean stream and serve as food for the fish. If the sludge deposits exert an oxygen demand, the oxygen may be depleted and offensive odors given off. In many cases the gases given off contain hydrogen sulfide. The sulfides may react with paints on buildings, boats, and structures to discolor the paint.

In tidewaters the suspended solids are deposited in the calmer waters along the banks of the Merrimack River during low flow and high tide and then are exposed when the tide is out. In certain areas an odor nuisance results. Behind the dams at Lawrence and Lowell, deep sludge deposits accumulate.

Suspended solids are particularly a problem in the Nashua River. Paper fibres can be seen along the banks of the stream, deposited there during higher flows. The stream passes through a number of ponds and impoundments, resulting in settling of the suspended matter. The solids decompose on the bottom, and in many cases the decomposition gases buoy up the sludge and the black sludge floats on the stream surface causing very unsightly conditions. Gas bubbles can be seen at many locations along the Nashua River. During one visit the river at the Route 225 bridge in Groton had an intense

foul odor, was dark gray in appearance, and had much floating scum. This was truly a very sick river.

On the North Nashua River within and below Fitchburg, Massachusetts, the water has a white color and there are many floating solids and sludge banks visible.

OXYGEN DEMAND AND DISSOLVED OXYGEN

Both sewage and industrial wastes contain organic matter which decomposes and exerts an oxygen demand in the receiving stream. If the dissolved oxygen (DO) is reduced below an adequate level, the fish population and the aquatic life on which the fish feed are reduced. Most water pollution control agencies have adopted an average of 5 mg/l as the minimum DO that is adequate to maintain the maximum potential sport fish population.

Both Massachusetts and New Hampshire have adopted 5 mg/l as one of the minimum standards of quality for Class C waters. One of the definitions of Class C waters is: "suitable habitat for...common food and game fishes indigenous to the region."

Dissolved oxygen data for the Merrimack River were obtained during the last part of July and the first part of August 1963 by the Massachusetts Department of Public Health. The New Hampshire Water Pollution Commission obtained similar data from above the Nashua River confluence to below the state line from early June to the middle of August. Flows in the river during June were considerably higher than

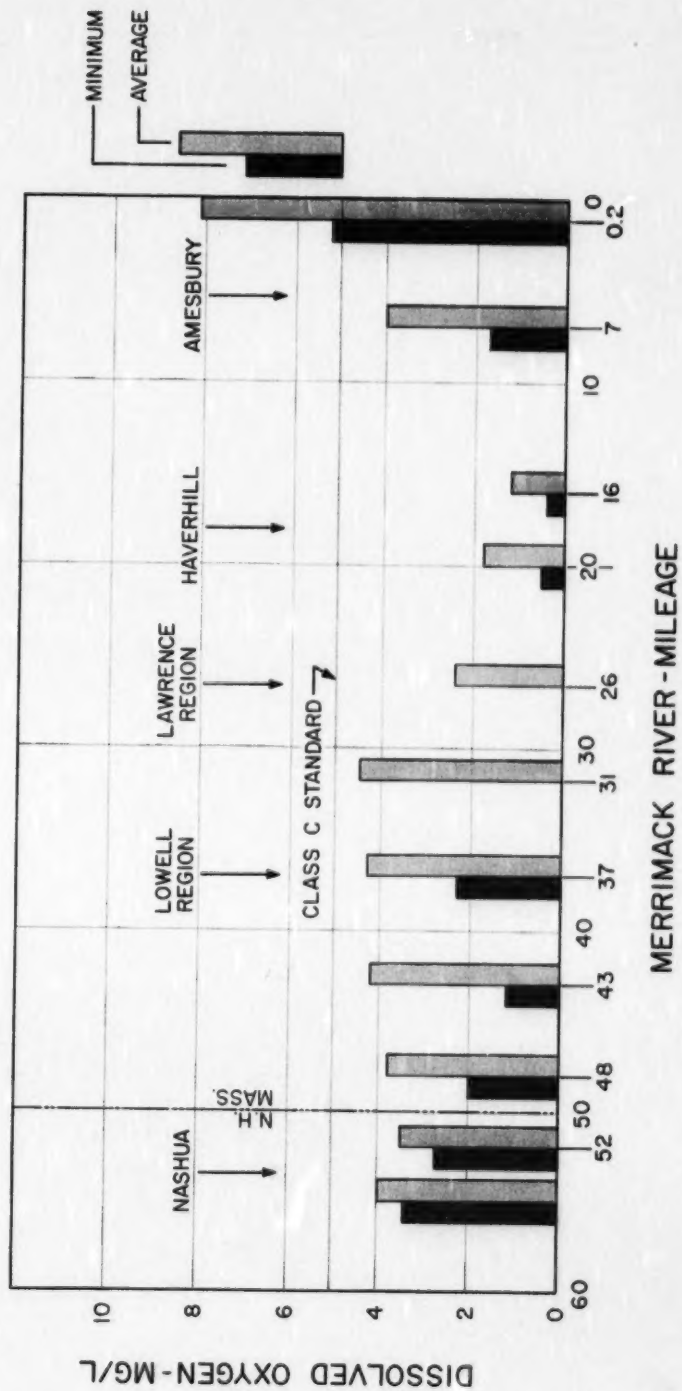
during the July-August period and, as expected, resulted in higher dissolved oxygen values in the earlier samples obtained by the New Hampshire Water Pollution Commission. Therefore, to make the data from both states comparable and to analyze the dissolved oxygen conditions during the critical-flow, high-temperature period, only the New Hampshire data from the middle of July to the middle of August were used. The average and minimum values obtained during this period are shown graphically in Figure 5 for various sampling stations along the Merrimack River.

Except for the station near the mouth of the river where considerable dilution from the ocean was received, the average values for dissolved oxygen during the low-flow, high-temperature period were at or below 4.5 mg/l for the entire reach. The average dissolved oxygen below Haverhill was only 1.2 mg/l. Between Lowell and Lawrence and between Lawrence and Haverhill, zero dissolved oxygen values were obtained, indicating very serious conditions in the stream for fish life even if for short periods. Values between the state line and Lowell were as low as 1.2 mg/l. This sample was obtained 350 feet upstream of the Southwell Combing Company and on the opposite side of the river from this outlet. Along with another very low oxygen value of 2.2 mg/l at this sampling station three hours later, the results indicate a serious oxygen deficiency, undoubtedly resulting from upstream discharges. This conclusion tends to be confirmed by samples obtained by the New Hampshire Water Pollution Commission at

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DISSOLVED OXYGEN VS MERRIMACK RIVER MILEAGE

FIGURE 5



Tyngsborough Bridge during the period of 1963 being analyzed. The average dissolved oxygen of these samples was only 3.5 mg/l.

From the dissolved oxygen standpoint, the Nashua River below the North Nashua River confluence is also in very poor condition. Throughout most of its length in Massachusetts, the dissolved oxygen is less than 50 per cent of saturation during the warm, low-flow period of the year and at times is at or near zero for considerable distances. The North Nashua is about 80 per cent of saturation above Fitchburg, but the dissolved oxygen decreases rapidly between Fitchburg and Leominster to as low as 20 per cent of saturation. Reaeration from rapids increases the DO in some reaches but is inadequate to prevent excessive depletion.

Intense algae blooms have been observed in the Nashua River in Pepperell and in New Hampshire. Undoubtedly these blooms are caused by nutrients from the combination of treated and untreated sewage and paper mill wastes. The series of ponds in the lower Nashua provide favorable habitats for algae growth. Dissolved oxygen data obtained near the Massachusetts-New Hampshire state line indicate typical effects of the algae that produce oxygen during the daylight but not at night. The diurnal fluctuation results in ranges of oxygen from supersaturation to near depletion.

During the period July 14-24, 1963, countless thousands of non-game fish were killed in the Nashua River near the Massachusetts-New Hampshire state line. The area affected covered 15 to 20 miles

of stream. Observers attributed the kill to depletion of dissolved oxygen.

On July 27-28, 1963, another severe fish kill occurred in which thousands of fish were destroyed, this time below Manchester, New Hampshire. The kill resulted when flow was reduced for the weekend at Amoskeag Dam just above Manchester in order to conserve the water for peaking power during the week.

MISCELLANEOUS

Personnel of the Lowell Water Treatment Plant have complained of high concentrations of ammonia in the raw water. This ammonia combines with the chlorine added for disinfection purposes so that it is difficult to obtain the proper concentration of free residual chlorine. Some of the ammonia undoubtedly results from the discharge of sewage upstream. Water plant personnel counteract the ammonia by adding more chlorine, which increases the treatment costs.

Oil slicks and floating grease have been observed in the Merrimack River on several occasions. These may adhere to boats or other objects in the water and make the river less desirable for recreation.

The carbon chloroform extract (CCE) test is a measure of certain organic chemicals in a stream. Pesticides and various petrochemicals are examples of materials which are detected by this test. A CCE limit of 0.2 mg/l has been established for treated water. Four

river samples obtained in 1962 between Lowell and Haverhill had CCE values ranging from 0.3 to 0.7 mg/l. In August 1963 a sample at the Lowell water intake also exceeded 0.2 mg/l. Activated carbon is used to reduce these chemicals in the water, along with tastes and odors, but adds to the treatment cost.

In June 1963 nitriles, or organic cyanide compounds, were found in the raw water pumped to the Lowell water plant.

In 1962 an accidental spill of an organic chemical used in making plastics occurred at a Leominster, Massachusetts, industry. This chemical was traced all the way down the Nashua and Merrimack rivers.

The potentially toxic chrome wastes and plating wastes which are discharged by two Nashua industries without any known treatment have already been mentioned in Table 1. Periodic fish kills may result from these wastes.

On August 22, 1963, hundreds of fish were seen dying in the Merrimack River just below the confluence of the Nashua River. The cause may have been toxic conditions from an industrial discharge in the city of Nashua.

AESTHETIC CONSIDERATIONS

The adverse effects of floating solids on the beauty of the Merrimack River has already been mentioned. Other materials contribute to the opinion of the public that the Merrimack River system is badly

polluted. For example, some of the business establishments in Lowell apparently dispose of their trash by throwing it out the window into the canal system to be carried into the Merrimack.

Condoms may be observed floating on the Merrimack River surface or washed up on the river bank at numerous locations. These detract from the enjoyment of the river for boating, swimming, or water skiing.

The Merrimack River has a black color which renders its appearance unsightly. Part of this apparent color is due to the black sludges on the bottom. The actual color is due not only to natural causes but also to industrial operations. This undesirable appearance may affect property values along the river and may reduce the river's appeal for recreational purposes. The color matter makes it more difficult to see a swimmer or water skier who is in danger of drowning and is below the water surface. It also increases the cost of municipal water treatment necessary to remove it.

White suspended matter from some of the paper mills in the Nashua Basin greatly detracts from the aesthetic value of this river. The turbidity is probably due to materials such as titanium dioxide which are used to give the paper a whiter appearance.

COMBINED SEWERS

Seventeen of the municipalities in the study area have combined sewers. Combined systems, which are common in older municipalities throughout the country, receive both domestic sewage and storm water.

It is not economical to design sewage treatment plants to treat the large quantities of sewage and storm water which enter combined systems during storms. As a result, overflow devices are provided to bypass portions of the mixed storm flows from the system to the nearest watercourse without treatment. Thus, the raw sewage diverted during storms intermittently causes pollution of the receiving stream even after treatment has been provided for dry weather sewage.

Control of this type of intermittent pollution can be accomplished only by provision of separate sewers for sewage and storm water, by storage units which temporarily hold the mixed flows and bleed them back to the treatment plant when flows are lower, or by the installation of suitable treatment works for the mixed flows in addition to treatment works for the dry weather flows.